AD 741016

NR 046-775

Final Report on Contract Nonr-591(14)
(RPI Project 453.06)

The contract was "to conduct research in radio astronomy relating to the effects of solar activity on the ionosphere and interferometric studies of the sun at 517 mc, including continued effort toward the completion, testing and evaluation of the receiving equipment."

Phase A, the effects of solar activity, was accomplished as proposed. The observations were published in Rensselaer Observatory Publications monthly, and copies were sent to ONR at the time of publication.

Phase B, continued effort toward the completion of the interferometer, was pursued vigorously, but due to certain difficulties which were detailed in the status report of 1960 January 27, the interferometer was not actually in operation during the contract period (16 June 1959 to 15 June 1960).

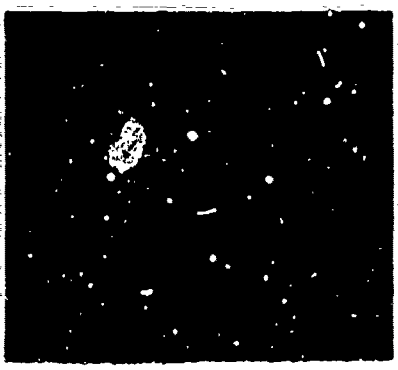
However, the interferometer was in successful operation by November 1960, and has been operated almost continously since then. A report on its operation was presented to the American Astronomical Society in December 1960 (a copy of this report is appended). A description of the equipment for formal publication is in preparation at the present time.

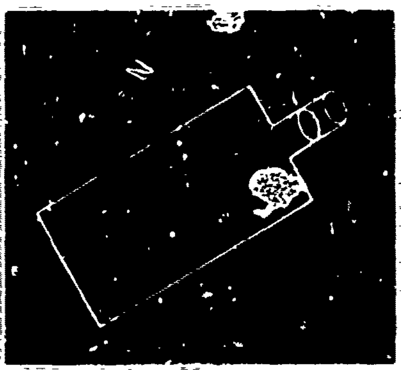
During the spring of 1961, the interferometer records indicated two cases of transverse motions of the source of solar burst radiation. That is, the source moved horizontally in the solar atmosphere instead of vertically as usual. The extent of the motion is approximately one half a solar diameter. Similar motions have been detected at other frequencies in Australia (unpublished), and optical evidence for such motions has been found by Moreton in this country. We do not yet, however, have a coincidence of the optical and radio events.

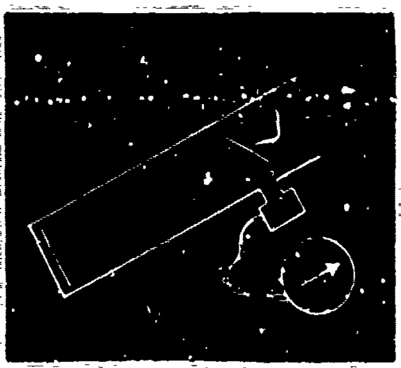
Robert Fleischer
Principal Investigator

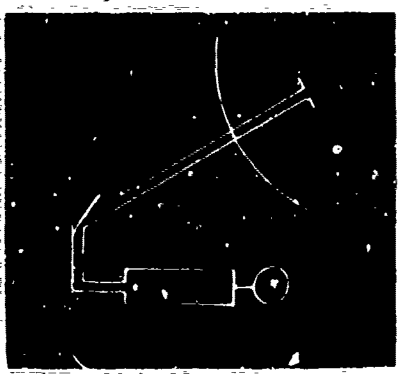
1961 December 22

23









RENSSELAER OBSERVATORY

Memorandum

POSITIONS OF 517-MEGACYCLE SOLAR BURSTS

Robert Fleischer and Masakazu Oshima

Number 33

1960 December

Observatory of
Rensselaer Polytechnic Institute
Troy, New York

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Positions of 517-Megacycle Solar Bursts

A paper for presentation to the 107th meeting of the American Astronomical Society, 1960 December 30

by Robert Fleischer and Masakazu Oshima
Observatory of Rensselaer Polytechnic Institute
Troy, New York

Abstract

A 517-megacycle swept-lobe interferometer has been placed in operation at the Sampson Station of the Observatory of Rensselaer Polytechnic Institute. The spacing of the elements is 200 feet, giving a lobe spacing of 32.7 minutes of arc on the meridian. The fringe pattern is moved forward at the rate of 30 fringes per second, linearly with time. As the sun moves across the sky, a phase recorder indicates in a saw-tooth pattern the position between the lobes occupied by the "center of gravity" of the radiation from the sun. The total intensity of the solar radiation is also recorded.

When a solar burst occurs, the center of gravity of the radiation moves to the east or west dependent on the location of the burst. The amount of the shift can be measured to an accuracy of 1 or 2 minutes of arc.

Preliminary results for seven burst events between August and November are presented and discussed. The locations of the sources of the 517-megacycle radiation are found to be consistent with the positions of the associated optical flares.

The time resolution of the present recording equipment permits the detection of angular motion for Type IV bursts in which the 517-megacycle radiation is present for times of the order of a minute or more. Of the four Type IV events discussed; two were located near the center of the solar disc and showed no detectable angular motion. Of the two near the western limb, the source of one moved westward at a velocity of 2,500 km/sec. This event had no associated flare or geophysical effect. The other limb event was of low intensity, and the motion, if any, is inconclusive. This event was accompanied by a flare and a sudden cosmic noise absorption.

<u>Instrumentation</u>

At Rensselaer we have constructed and placed in operation a swept-lobe interferometer operating at [illegible]7 megacycles for the purpose of measuring the positions and motions of the sources of solar bursts at that frequency.

The first swept-lobe interferometer for solar studies was constructed by Little and Payne-Scott in Australia in 1949, operating at 97 megacycles. A swept-frequency interferometer operating in the range of 40 to 70 megacycles was constructed at Sydney by Wild in 1953. Other low frequency interferometers of similar nature are located at Boulder (Warwick) and in Ottawa (Hartz), the latter operating at the single frequency of 52 megacycles. As far as we know, ours is the only such equipment in our frequency range, about 10 times the frequency of the others. This has the advantage of reaching somewhat further [illegible] the [illegible] corona or upper chromosphere.

Slide 1

Minnaert's Figure 1

The relationship of wavelength to the height from which it escapes in the vicinity of a solar disturbance is indicated roughly on the first slide, taken from Minnaert's summary discussion at the Paris Symposium. Our wavelength is 60 centimeters.

The interferometer itself consists of two 14-element Yagi antennas on equatorial mounts as shown in the next slide.

Slide 2

Overall View of Interferometer

In this picture we are looking from the west. The antenna closest to us and the one farthest from us at the right of the picture are separated by 200 feet, or 105 wavelengths, leading to a lobe spacing of 32.7 minutes of arc. The antennas are placed on towers to minimize the effects of irregular ground reflections. The third antenna, the middle one on the picture, will be used intermittently in place of the nearest or westernmost antenna to give a separation of 150 feet, with a larger lobe spacing. This will make it possible to fix which lobe contains the source and to study the polarization of the bursts; this feature of the interferometer is not yet operating.

An earlier version of the electronics was described to Commission V of URSI at the spring meeting of 1958. The present system is in principle the same although every detail has been considerably improved through the careful work of Mr. Oshima, especially from the point of view of phase stability of the components. The lobes are swept by changing the phase of the local oscillator at the east end of the array by exactly 360° in 1/30 of a second. This is repeated at 30 cycles per second. The sweep is equivalent to

continuously shifting the fringe pattern from east to west linearly at 30 fringes per second. A fixed point of radiation in the sky would result in a 30 cycle per second output whose phase is dependent on the position of the source on the sky.

Slide 3

Interferometer electronics

As the source travels from east to west across the sky the output of a phase detector changes from 0° to 360° as the source goes from one interferometer fringe to the next. This is shown on the phase recorder at the right in which one can see the sun moving through the lobe pattern.

If a burst source appears away from the center of the solar disc, there will be a corresponding shift of the phase record. This is shown on the next slide.

Slide 4

1960 August 6, 1311 UT

in which we see the sudden change of phase as the burst appears. The upper trace gives the record of the intensity, unfortunately on a

somewhat different time scale. Corresponding times are marked on the two records. The position deduced from the phase record is that of the center of gravity of the burst and the solar disc. By knowing the relative intensities of the burst and the quiet sun, one can project this to the position of the burst source.

As the distribution of the 500-megacycle radiation from the sun is not uniform across the disc, the phase record may be shifted already even before the burst occurs. We endeavor to establish this by using the IBM 650 computer to predict the times during the day when the phase should be equal to 0, assuming that the center of gravity of the 500-megacycle radiation from the quiet sun is identical to the center of the visible solar disc. The machine calculation also takes into account a standard refraction. After the records of the quiet sun are analyzed for a period of perhaps a year, these predictions will enable us to compute and then allow for the effects of ground reflections at the site.

In the case shown here the phase shift corresponds to a displacement from the center of the sun of 15.4 minutes eastward for the duration of the event. If the intensity of the burst were constant, or if it were large as compared to the quiet sun so that the center of gravity of the radiation effectively represented the position of the burst, then a motion of the source of radiation relative to the sun would show up as a change of the slope of the phase record from the case for the westward motion of the sun itself across the sky. This change might take place slowly and be almost undetectable in the absence of the computer predictions, which is another reason we depend

on them. It is evident that a shift in the center of gravity could occur gradually if the intensity of the burst source were changing, so that it is important to have the intensity records especially for the weaker bursts.

Slide 5

Observed 517-Megacycle Events

Catalogue of events:

The interferometer was operated in a temporary location during the month of August and during September and October was moved to its final location. During August and November there were 7 events which showed conspicuously on either the intensity or the phase records.

A catalogue of these events is shown on the slide. The times are Universal Time. The event on November 12, the spectacular large flare, was in progress when the equipment was started in the morning; the flare was observed to begin at 1325. The intensities are given in units of the intensity of the quiet sun. The scale of the intensity recorder was changed so that the later observations would indicate intensities up to 8 on this scale. For intensities greater than this the position deduced from the phase record is essentially the position of the burst source and one no longer needs to correct for the contribution of the quiet sun.

The positions deduced from the phase records are shown. The position of the event of August 11 is ; unfortunately this position was omitted in the preparation of the slide. The letters

E and W refer to the component of the shift in a direction perpendicular to the interferometer fringe. Dependent on the hour angle, the interferometer fringe may be at a considerable angle (even up to 90°) from the hour circles on the sky or from the central meridian on the sun. In the positions which are given no correction has been made for curvature of the ray path in the solar corona nor has any effect of solar latitude been considered, whence the given distances are the minimum possible ones relative to the solar center.

The column headed "Fl" gives the importance rating of the associated solar flare. The positions of the flares, when known, agree with ours to 1 or 2 minutes of arc or better. The column headed "Burst" gives the burst classification kindly supplied by Dr. Haddock's group at the University of Michigan, except for the third event which coincided with a type 2 burst observed at 2,800 megacycles at Ottawa. The column headed "M" refers to motion found in the present study. There is one clear cut case of motion observed on November 27 and one possible one on November 20.

The November 20 event was preceded by a class 1 flare at the western limb. The flare was observed from 2019 to 2023. One minute later the intensity at 517 megacycles increased, lasting for 41 minutes. The time 2033 is the time of maximum. Unfortunately the evidence for motion is inconclusive in this interesting case; our intensity records are not yet sufficiently well calibrated to provide the necessary projection factors when the intensities are weak and fluctuating.

On November 26, the intensity is quite low, leading to a large position uncertainty. The class 1 flare was in progress at 1630 at a position about 4.0 minutes E.

Slide 6

1960 August 11, 1926 UT

The event of August 11 was accompanied by a large flare and by ionospheric disturbances such as SCNA. The Michigan observers report a strong Type IIIg burst from 100 to 580 Mc from 1925.9 to 1928.8, with a very weak Type IV from 1926-1936.

Our records give the location of the 517-Mc source at 6'.8E from 1926.9 to at least 1931, so we take the association to be with the Type IV burst. The apparent slope of the phase record from 1926.0 to 1926.9 at the beginning of this event is probably not motion, but the effect of the shift of the center of gravity as the burst intensity grows. Any expected motion in this case would be small since the source is near the center of the disc.

Slide 7

1960 November 27, 1511 UT

This event was not accompanied by an observed flare or by any reported ionospheric event. A radio burst at 500 Mc from 1510 to 1513 is reported in the TR weekly report. Michigan reports a Type IV burst from 1510 to 1513 with frequency range 320 to 580 Mc, with the remark that it is possible that this event is really a group of very fine Type III bursts so close in time as to resemble a continuum.

At Rensselaer we observed that, after some forerunners from 1507 to 1510, the intensity began to rise at 1510, going off scale at 1511. The forerunners show on the phase record at the same position as the main part of the burst which followed. From 1510 to 1511.6 the position is constant at 14'.4W of the center of the solar disc. From 1511.6 on, for over one minute, the slope of the phase record changes indicating a projected westward motion of the order of 2,600 km/sec.

It seems probable that a group of Type III bursts would not show a time change of position in such a uniform manner. However, the derived velocity of 2,600 km/sec is a reasonable one for a Type IV burst as reported, for example, by Wild at the Paris Symposium from studies at a much lower frequency. Thus we conclude that this event is in reality a Type IV event.

Slide 8

Motions

Motions

There are four events of sufficient duration that motion of the source might have been detected; in only one of these (November 27) is the motion certain. In two of the remaining cases, the burst source is relatively near the center of the disc, which leads us to expect only small angular motions. One of these is the November 12 event which was associated with a cosmic ray increase and strong ionospheric disturbances. The remaining case (November 20) was a relatively low intensity burst near the limb, with gradual intensity changes which lead to inconclusive interpretation of motions.

All the events for which 517-Mc angular motions are present or possible are Type IV events. The one definite case was the only one of the four which did not have associated ionospheric effects. The significance of this is not clear, and it may only be that the associated flare was behind the limb; no flare observations are reported.

The detection of motions of Type III events is possible in principle as far as the interferometer equipment itself is concerned, but the time resolution of our presently available recording equipment is not sufficient to deduce changes in position in the short intervals of duration of these bursts.

Slide 9

1960 November 26, etc.

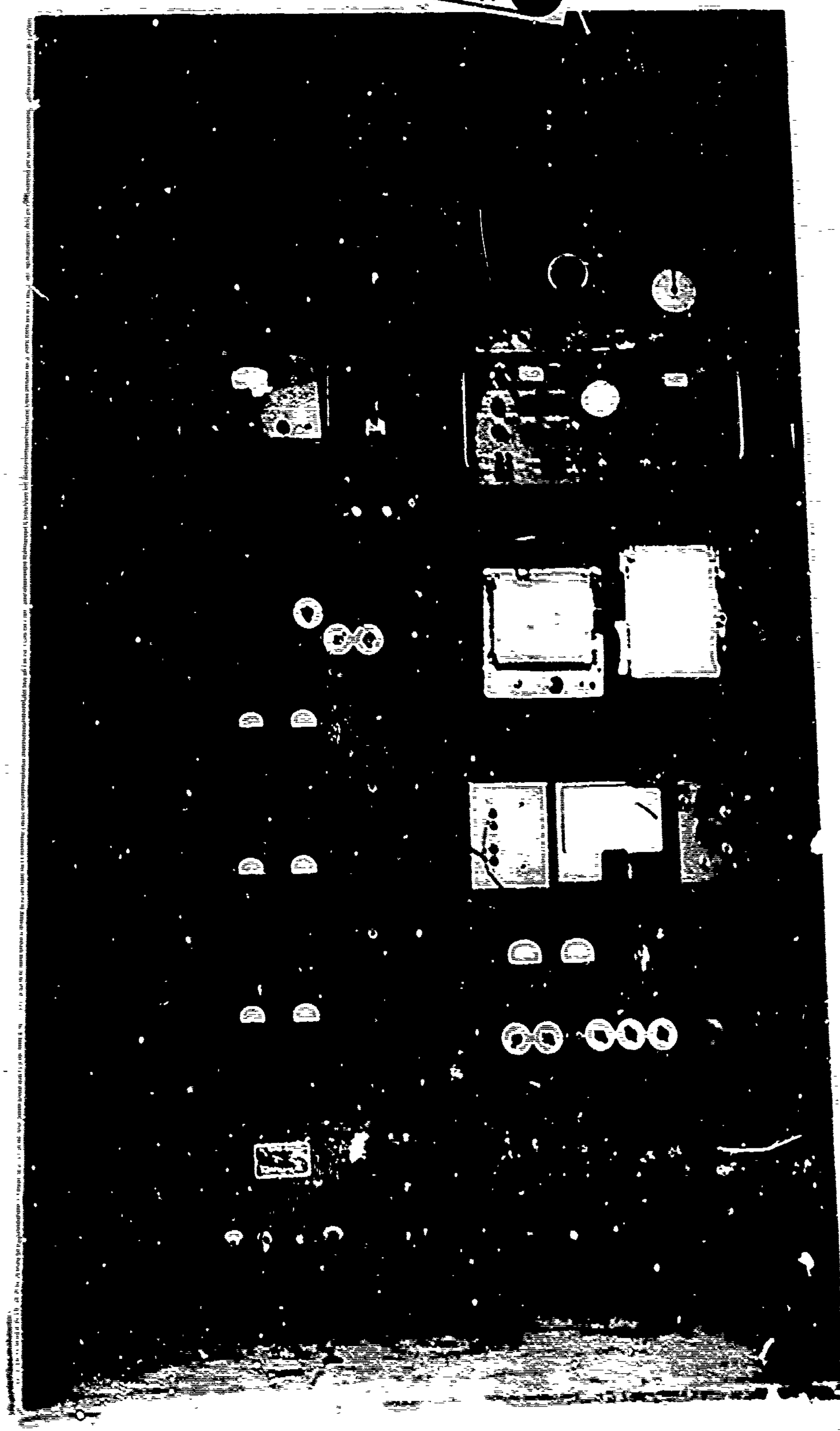
On some days the phase record becomes washed out when the sun is in the vicinity of the meridian. This we interpret as due to a limb brightening or slight increase in the effective diameter of the sun. Since the lobes are spaced 32'.7 at the meridian, an increase in diameter would mean that one interferometer lobe is always illuminated, and there is then no output at the 30-cycle sweep frequency.

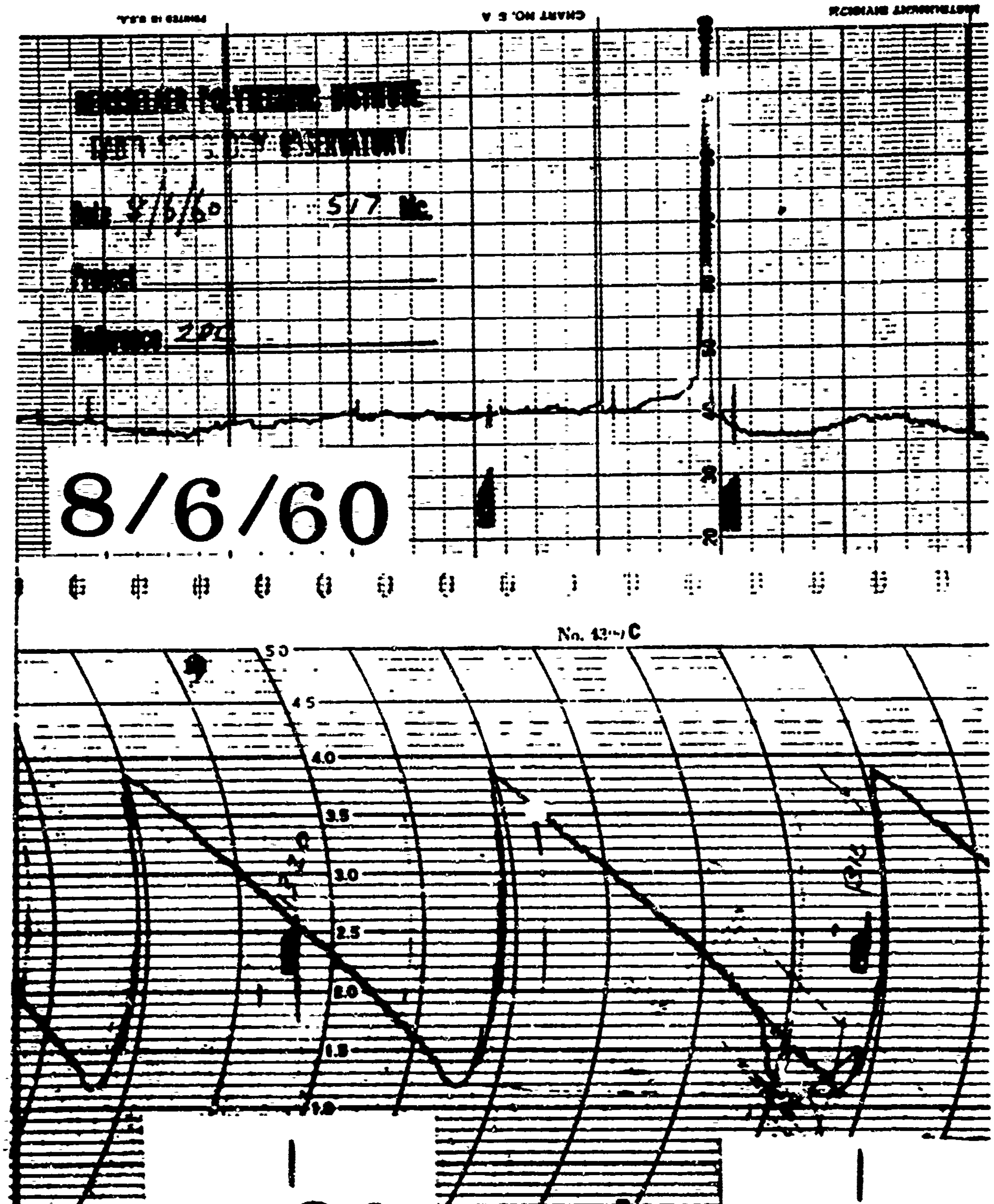
On November 26 when this situation obtained, the phase record became quite clear when a small burst occurred, which lends support to the interpretation of the wash-out effect. The effect does not seem to be correlated with weather at the ground. The effect of ionospheric seeing is a possibility, but this too seems to be ruled out by the performance during the burst event.

The interferometer array includes a third antenna which is to be used for resolution of lobe ambiguity. The wider lobe spacing which would be given by using this antenna would reduce the effect shown here. This antenna will be placed into operation when we secure the appropriate switches.

Lights

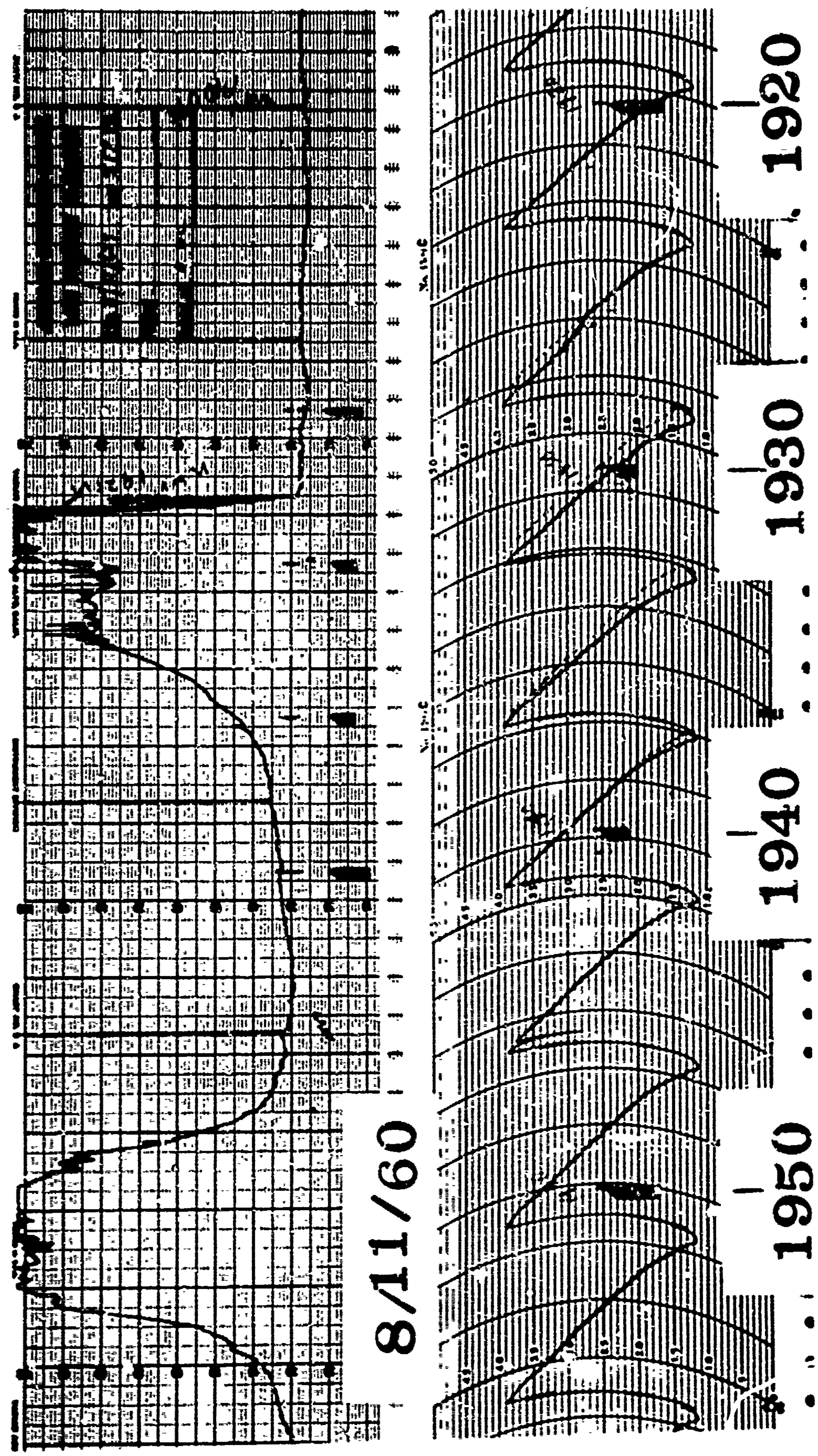
In conclusion, this has been a first report, indicating the types of observations which can be made with this equipment. We hope in time to have a larger volume of data so that we can establish the circumstances under which angular motions are to be found, and how the magnitudes of these motions are related to other characteristics of an event. We look forward to increasing the time resolution of the recorders so that we can detect motions of other types of sources, in particular Type III and reverse drift bursts, and to placing the third antenna in use to resolve lobe ambiguities and give polarization information.

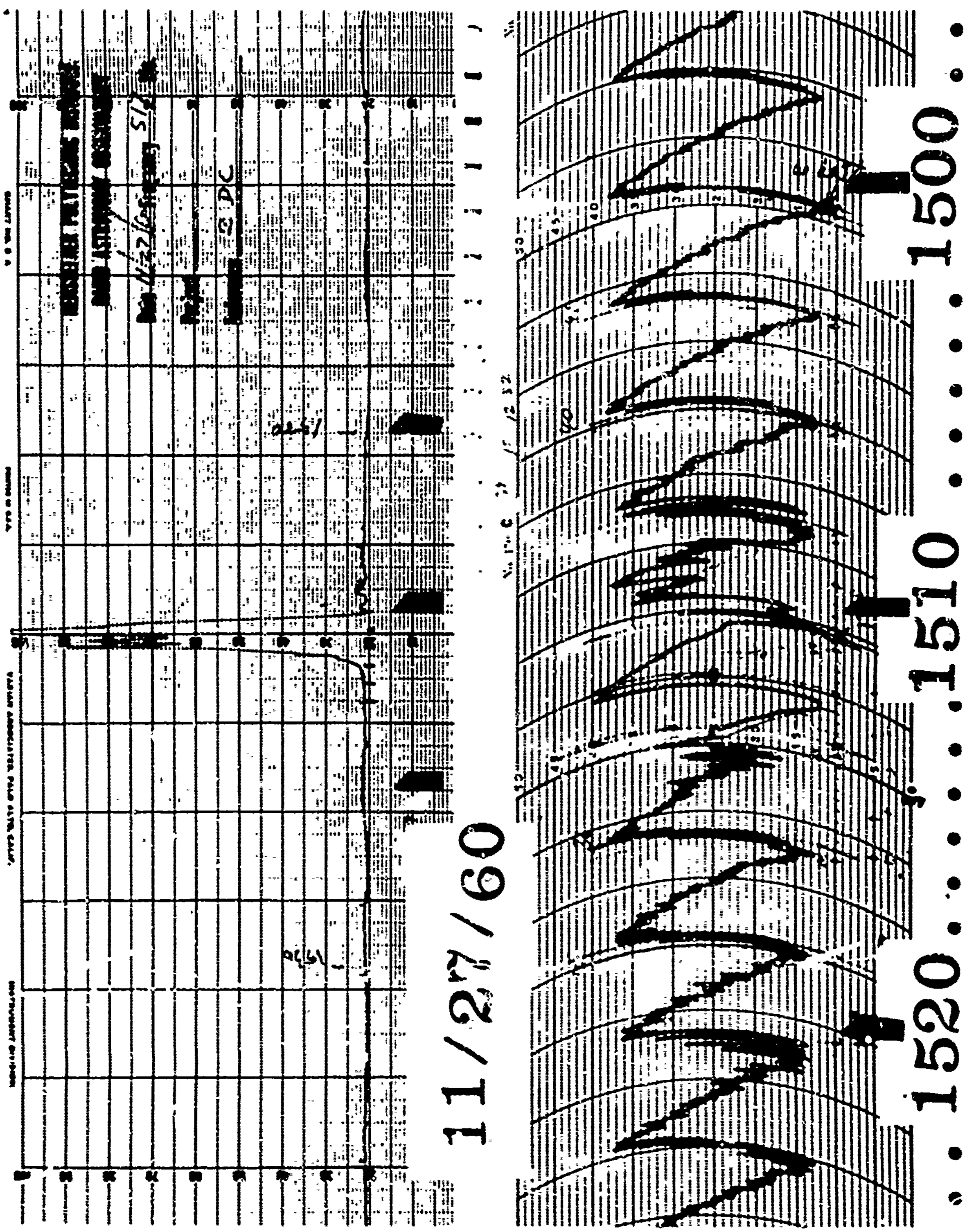



8/6/60
1320
1310

Observed 517-Mc. Events

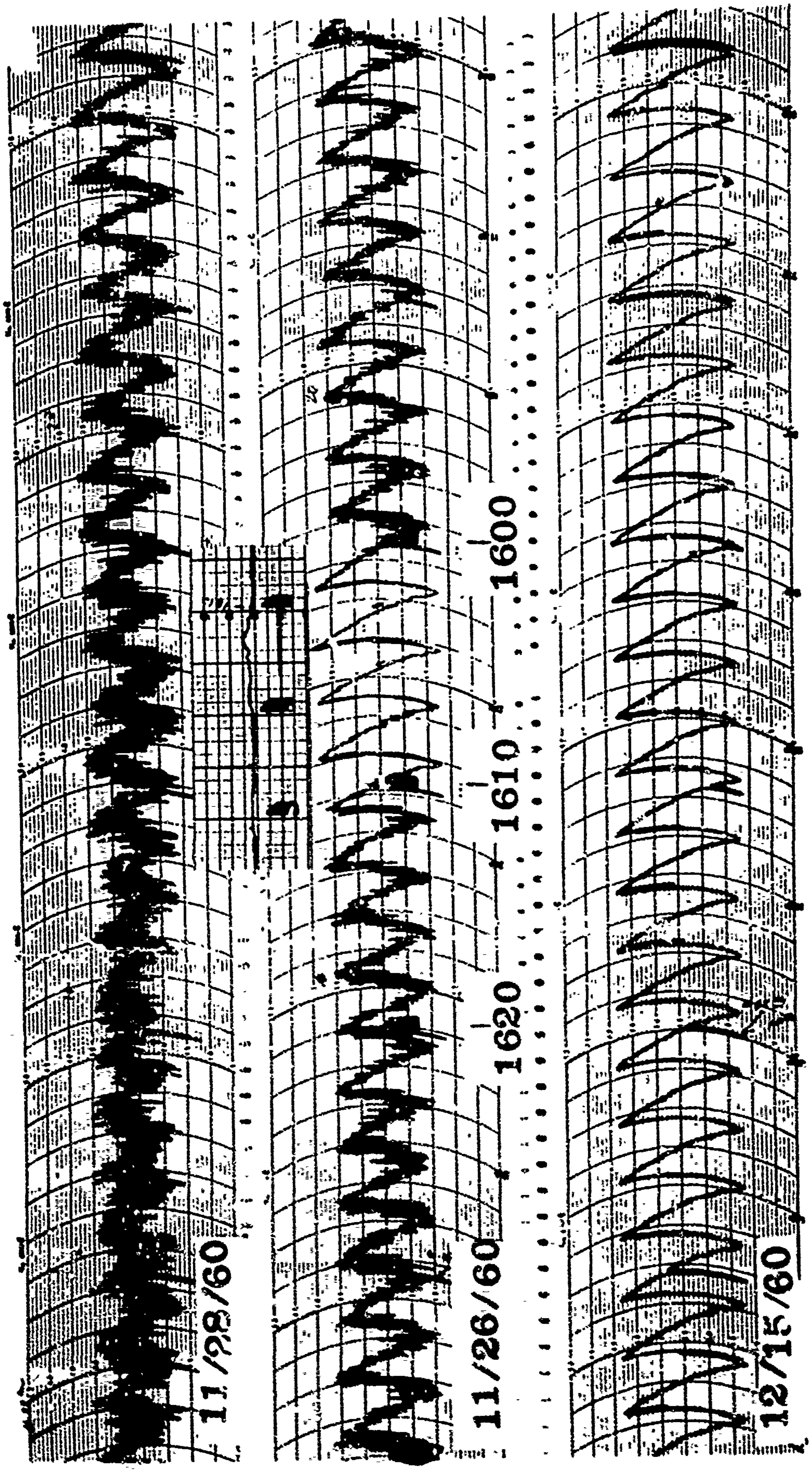
Date	Time	Int	Pos'n	Fl	Burst	M
8/6	1311	2	15.4E	2	IIIg	-
8/11	1926	>4	6.8E	3	IV	-
8/11	2004	>4	5.0E	1	Otc 2	-
11/12	b1330	>4	4.0W	3+	IV	-
11/20	20<u>38</u>	3.5	14.6W	(1)	IV	?
11/26	1610	0.4	3.0E	1	IIIg	-
11/27	1511	>8	14.4W	-	IV	x


8/11/60
1920
1930
1940
1950


11/27/60
1500
1510
1520

Motions

	Pos'n	Motion	SCNA	Date
IV	14.4W	Yes	No	11/27
IV	14.6W	?	Yes	11/20
IV	4.0W	No	Yes	11/12
IV	6.8E	No	Yes	8/11


11/28/60
11/26/60
12/15/60
1600
1610
1620